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DRES UNMANNED AERIAL VEHICLE DATA LINK RESEARCH

by

Thomas E. Ollevier

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EXECUTIVE SUMMARY

The Unmanned Vehicle Systems Group (UVSG) at Defence Research Establishment Suffield (DRES) carries out research in the area of Unmanned Air Vehicles (UAVs) and their associated control systems. The major focus of this research is the command and control of UAVs. The command and control system of a typical UAV system consists of the airborne command and control system (ACCS), the ground control station (GCS), and the data links required to enable communication between the ACCS and the GCS. This report describes the data links presently used by DRES and the proposed improvements to these systems.

This report provides background on work carried out in the past by the UVSG with the emphasis on how this work has affected the design of UAV data links at DRES. The requirements of both operational and research UAV data links are also described. The report proposes a possible frame work for future research in the area of data links for UAVs including a proposal for research into the feasibility of steerable antennas for UAVs. The work would commence with the integration of existing antenna system elements with the UAV autopilot being utilized as the antenna controller. At the same time work would begin on the design of a steerable antenna with a gain of approximately 10dB. This work would provide a basis for the design of higher gain UAV data link antennas and special purpose antennas such as those required by communications repeaters and sonobuoy repeaters.

ABSTRACT

The Unmanned Vehicle Systems Group (UVSG) at Defence Research Establishment Suffield (DRES) has a mandate to conduct research in the area of Unmanned Air Vehicles (UAVs) and their associated control systems. The major focus of this research is the command and control of UAVs. The command and control system of a typical UAV system consists of the airborne command and control system (ACCS), the ground control station (GCS), and the data links required to enable communication between the ACCS and the proposed improvements to these systems.

The improvements described include the implementation of low probability of intercept (LPI) technology in the UAV data link. Brief descriptions of the benefits of spread spectrum modulation and directional antennas are presented. Possible areas of research in the development of directional antennas for UAVs are presented along with a description of how research in this area would proceed in the future.

RÉSUMÉ

Le Groupe des systèmes de véhicules sans équipage (GSVSE) du Centre de recherches pour la défense Suffield (CRDS) a pour mandat d'effectuer de la recherche portant sur les véhicules aériens sans équipage (VASE) et leurs systèmes de commande. Cette recherche est surtout axée sur la commande et le contrôle des VASE. Le système de commande et de contrôle d'un VASE type se compose du système de commande et de contrôle aérien (SCCA), de la cabine de contrôle au sol (CCS) et des liaisons de données nécessaires pour permettre la communication entre le SCCA et la CCS. Le présent rapport décrit les liaisons de données utilisées actuellement par le CRDS et les améliorations prévues de ces systèmes.

Les améliorations prévues comprennent la mise en application de la technique de faible probabilité d'interception (FPI) dans les liaisons de données pour VASE. On décrit brièvement les avantages offerts par la modulation à spectre étalé et les antennes directives. On traite des domaines possibles de recherche en matière de mise au point d'antennes directives pour VASE et on explique de quelle façon la recherche dans ce secteur devrait s'effectuer dans le futur.

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INTRODUCTION

The Unmanned Vehicle Systems Group (UVSG) at Defence Research Establishment Suffield (DRES) has a mandate to conduct research in the area of Unmanned Air Vehicles (UAVs) and their associated control systems. The major focus of this research is the command and control of UAVs. The command and control system of a typical UAV system consists of the airborne command and control system (ACCS), the ground control station (GCS), and the data links required to enable communication between the ACCS and the GCS. This report describes the data link component of the command and control system.

This report begins with a section which provides background on the existing DRES UAV subsystems with the emphasis on how the various systems interact with particular attention being given to the data link system. This is followed by a section which outlines future improvements which can be made in the data link system through both in house and contracted research effort. These improvements would focus on both simplifying the structure of the UAV communications systems on the whole while at the same time introducing features which would make the data link much less susceptible to interference and detection. The final sections of the report provide an overview of one possible future research direction which would focus on the design of medium to high gain steerable antennas for use on an UAV.

BACKGROUND

Unmanned Aerial Vehicle systems are complex systems which have the potential to act as force multipliers on future battle fields. UAVs have proved their usefulness on the battle field over the past three decades. They have been used in such roles as, providing timely intelligence information on hostile force deployments, and as decoys to protect both human lives and valuable military assets such as aircraft.

The major subsystems of a UAV system are;

- the airframe,
- the autopilot/guidance system,
- the sensor (payload),
- the data and command link, and
- the ground control station.

Most of these systems exist in one form or another for use in manned aircraft; however, UAVs require special adaptations of these systems. To be practical, UAV systems must be small and lightweight for operation within the physical dimensions and weight restrictions imposed by the vehicle airframe. UAV systems must have fault tolerance designed in from the conceptual design stage as there is no on board pilot to oversee their operation. The performance of the overall UAV system is determined by the reliability of the weakest subsystem utilized; therefore all of the subsystems must be able to interact reliably and predictably for the system to perform properly. As an example of the interdependence of subsystems, the UAV can be equipped with the best sensor system available but if the data link can not transmit the sensor data reliably to the ground control station (GCS) there is no use in deploying the vehicle.

DRES has had experience in designing and building most of the subsystems itemized above over the ten year life of the DRES UAV program. The background sections provide brief descriptions of the subsystems listed

above in terms of their effects on the design of the data link system. A brief description of the status of the current DRES subsystems is also provided.

The report then continues on with an expanded description of the required features of a UAV data link system. The existing DRES equipment is then described with emphasis on its deficiencies. The final sections of the report describe possible future research areas with emphasis in the area of antenna design.

UAV Airframes

The design of the UAV airframe influences the design of the UAV data link system by dictating the configuration of the antenna system which can be used. The size and payload of the UAV will dictate the size and number of antennas which can be accommodated by the airframe and the configuration of the airframe will dictate the possible antenna mounting locations. In most cases to provide 360 degree coverage around the UAV, multiple antennas will have to be used. The locations available for installing antennas will partially determine the overall performance of the data link system. The ideal location for a UAV antenna system is a point on the airframe which maintains line of sight contact with the GCS regardless of the attitude of the airframe. At least one UAV system designer has hung an antenna pod from the bottom of the UAV to ensure that this requirement could be met.

A number of test bed airframes for UAV research have been utilized at DRES over the past ten years. These airframes have varied in complexity from very simple modified hobbyist style aircraft in the early 1980's to a fully instrumented Challenger II ultralight aircraft. These airframes have also been augmented through the use of manned aircraft, notably a Cessna 172 and a Piper Seneca. The majority of the current DRES UAV system research is based on the use of the Seneca aircraft operating as a surrogate air vehicle[1] for a UAV. The use of manned aircraft lessens the risk of catastrophic loss of research hardware due to failures of prototype hardware or software. The Seneca aircraft provides the necessary payload capacity for instrumenting and evaluating prototype UAV subsystems. This enables the performance of prototype hardware to be monitored under realistic flight conditions before it is flown in an unmanned aircraft. DRES requires the use of UAVs such as the ultralight in the research and design cycle to validate system concepts under realistic operating conditions. The ultralight has a stall speed of approximately 30 knots

[1] A surrogate air vehicle is a small manned aircraft which is used to replace a UAV in a development program or for training purposes.

Figure 1: Seneca Test Aircraft

while the Seneca has a stall speed of approximately 80 knots. The lower speed of the ultralight more closely matches that required in a surveillance UAV which may be required to loiter about a target of interest.

The UAVs and manned aircraft are also useful as technology demonstration platforms which can be used to present operational UAV scenarios to the Canadian Forces. The airframes of both the Seneca and Challenger aircraft are large enough to allow the installation of any prototype payloads or data link systems which may be required by the UAV program. The Seneca and Challenger II aircraft are shown in Figures 1 and 2.

UAV Autopilots

The design of the UAV autopilot determines the level of autonomy at which the UAV system is capable of operating. The processing capabilities and input/output (IO) capabilities of the autopilot system dictate the numbers and types of flight control algorithms and hardware sensors which can be used in the control of the air vehicle. The processing power of the autopilot determines the amount of data which must be passed between the GCS and the UAV in order to control the UAV. The volume of data which must transmitted between the GCS and the UAV directly impacts the design of the data link control and telemetry subsystems by setting a minimum bandwidth for the data link.

Research in autopilot hardware and software architectures has been a

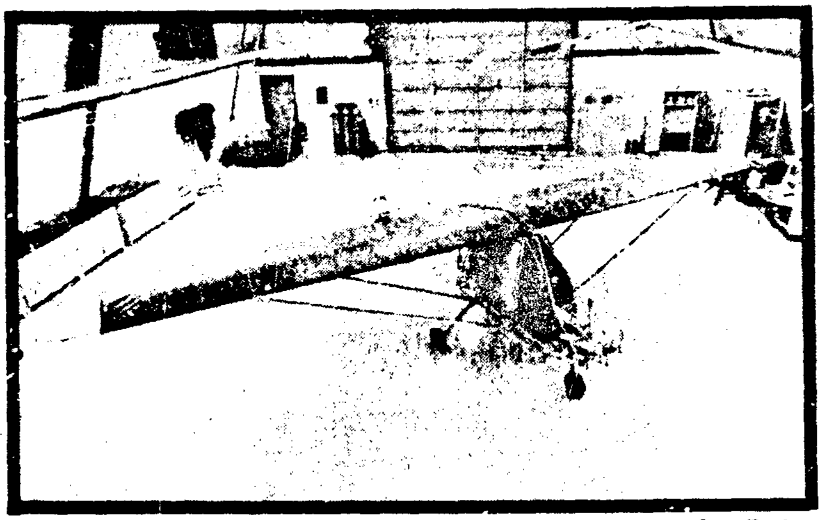

Figure 2: Challenger UAV

major part of the UAV program at DRES for the past several years. Initial DRES autopilot research consisted of designing low cost autopilots for aerial targets. The design of autopilots for targets became necessary when the increased range and performance requirements of the targets made it impossible for an operator to visually control the targets. Over time these early autopilot designs have been refined, redesigned and upgraded to handle more demanding roles such as those required of a simple surveillance UAV. Recently the design of a new autopilot was undertaken as the performance capabilities of the existing autopilot were rapidly being reached. A distributed processor architecture was chosen for the new autopilot to enable future expansion of the autopilot without a major redesign of both the hardware and software being required. A modular design was chosen for the new autopilot as it was felt that this would facilitate the incorporation of fault tolerance at the present time as well as enabling expansion of the autopilot's capabilities in the future. The new autopilot is based on computing elements (CE) and input/output modules (IOM). A complete autopilot consists of one or more CEs and one or more IOMs. The CEs are connected by a network consisting of duplicated fiber optic links while the IOMs are connected by wired links to the CEs. The standard IOM has four A/D channels and includes a digital signal processor which is used to filter the incoming data. The IOMs also have built in pulse width control outputs for controlling servos. The architecture of the autopilot makes it possible to design custom IOMs to interface with new sensors.

Custom IOMs may be required to interface with new payloads or to perform dedicated functions such as controlling steerable UAV antennas.

UAV Payloads

The bandwidth requirements of the payload determine the bandwidth of the data channel required to transmit the output of the payload to the GCS. The primary payloads used by DRES in UAVs have been optical payloads in the form of commercial black and white video cameras. The performance of these low cost optical sensors in UAV surveillance and targeting roles is suitable for demonstration purposes and under some conditions may even be acceptable in operational roles.

Optical UAV payloads can vary from the simple video cameras utilized in the DRES program to forward looking infrared (FLIR) and infrared line scan (IRLS) sensors. Other payloads of potential interest are miniature radars, electronic support measures (ESM) packages, electronic counter measures (ECM) packages, and data link repeaters. If future DRES research requires the use of one of these sensors it would be procured as an off the shelf unit which would be used to demonstrate the feasibility of using the technology in a particular role. DRES's present plans call for the continued use of video sensors equipped with stop action shutters and sensor elements with varying levels of light sensitivity. The bandwidth of these video sensors is as wide as or wider than would be generated by any of the other potential UAV payloads, therefore the data link system research carried out at DRES will be applicable to practically any UAV payload.

UAV Data Links

The design of a UAV data link system is influenced by many factors. The basic requirements of a UAV data link system are to relay commands from the GCS to the UAV and to relay status and payload data from the UAV to the GCS. The data link must also be capable of generating information on the position of the vehicle and most importantly it must be capable of carrying out all of its functions without revealing the location of the GCS to hostile forces.

Depending on the operational use of the vehicle and the type of payload utilized the data link may transmit either raw or preprocessed data. Some examples of preprocessing are data compression or the use of error detecting/correcting codes to improve the robustness of the transmitted data.

DRES has used a broad spectrum of data/command links in the UAV program. The initial control links consisted of hobbyist type radio control units while the more recent control links have relied on digital command links and portable tracking radars. The data links presently used by DRES have been acquired as the result of a number of past projects and have been adapted to fit their present roles. The capabilities and deficiencies of the data link equipment presently used by DRES will be expanded upon later in this report.

UAV Ground Control Stations

The split in the overall work load between the GCS and the autopilot will to some extent determine the amount of command and control data which must be transmitted over the data link. The requirement to conceal the location of the GCS from hostile forces makes necessary the use of low probability of intercept (LPI) technology in the design of the data link.

In the recent past, research into the design of ground control stations has formed a major part of the UAV system work at DRES. This work has complemented the autopilot work and has resulted in the availability of highly flexible command and control components in both the GCS and the UAV. As a result of this work, a major R&D contract was put in place for the design of a testbed ground control station which will be used to evaluate operational concepts in UAV control. The design of the ground control station testbed is focused on making the testbed as flexible as possible so that changes in hardware or software can be rapidly implemented. In order for DRES to fully utilize the power of the new autopilot it will be necessary for DRES to acquire a reliable and flexible data link system.

UAV DATA LINKS

Operational UAV Data Link Requirements

UAV data link systems share many of the operational requirements found in other military data communication systems but, they also have additional requirements. The UAV data link must be able to transmit and receive low bandwidth command and telemetry data as well as transmitting and receiving the high bandwidth data typical of most UAV payloads. The data link system must also provide a basic backup tracking system to maintain control of the UAV in the event the primary navigation system becomes inoperable.

A block diagram of a UAV data link system is shown in Figure 3. The data link consists of the GCS and autopilot data link processors/interfaces, transmitters, receivers and antenna systems. The basic function of the data link is to facilitate control of the UAV by transmitting commands from the GCS operator to the UAV and by transmitting status data from the UAV to the GCS operator. The data link also transmits the wide bandwidth data from the UAV payload to the GCS. An ideal data link interface would allow the use of the multiple data formats required by different sensors. The data link should be capable of transmitting video data, line scan data, and digital or analog data from other payloads such as electronic warfare (EW) payloads.

In the GCS the configuration of the data link is controlled by the mission planning and control system (MPCS). The MPCS determines the rate at which data is transmitted to the UAV and the rate at which data is required from the UAV. The accuracy of the tracking system associated with the data link system is determined by the accuracy of the UAV position data required by the MPCS.

In the UAV the configuration of the data link system is controlled by the autopilot. If a steerable antenna is utilized by the data link the autopilot must supply antenna pointing data to the antenna controller. The antenna pointing data is derived from the autopilots knowledge of the GCS location and the location and attitude of the UAV. The accuracy of the antenna pointing data required by the UAV data link antenna controller is determined by the gain of the antennas chosen for use on the UAV and the dynamics of the UAV. The

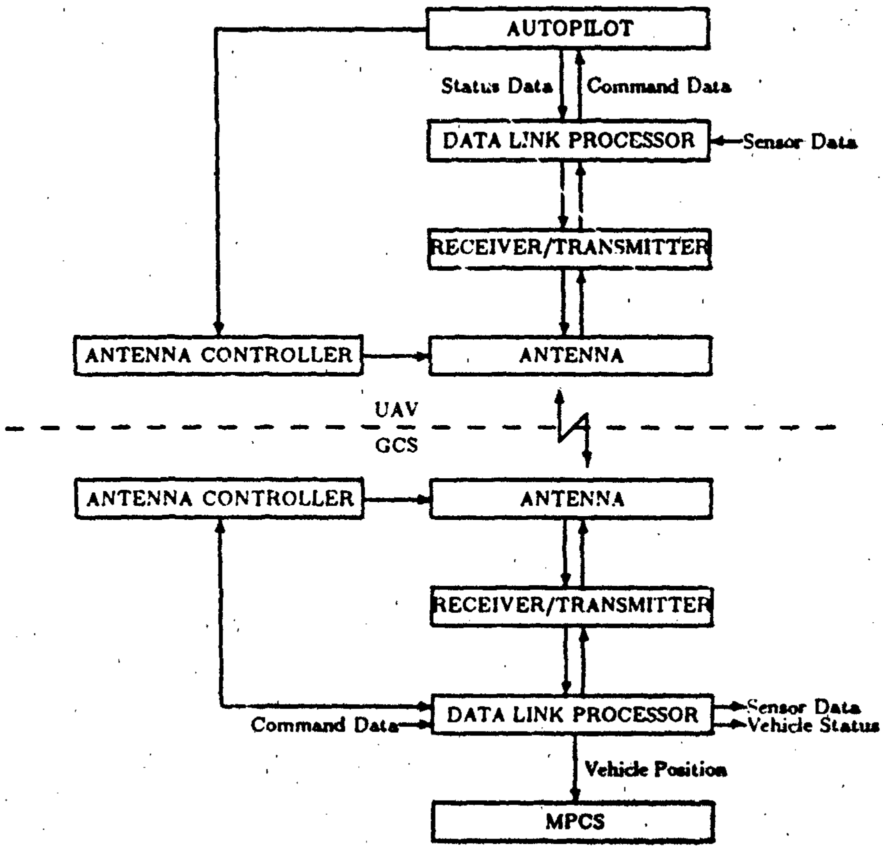

Figure 3: UAV Data Link Configuration

antenna control requirements are directly related to the gain of the antennas used; the higher the gain of the UAV antennas, the higher the level of antenna pointing accuracy that is required to ensure reliable communication. If the power output of the data link can be varied the autopilot is responsible for determining the appropriate output level based on the distance of the UAV from the GCS and the number of errors occurring in transmissions on the data link.

The data link must be capable of transmitting payload data which is encoded in different formats. The formats vary from high bandwidth analog and digital data generated by optical payloads, to medium bandwidth digital data generated by EW payloads down to low bandwidth house keeping data generated by data link repeaters. Compression of high data rate raw payload sensor data may be handled within the payload itself or by an optional data link module. The use of special purpose modules within the payload increases the weight and size of the payload but provides a more versatile data link for use in a research environment.

The radio frequency (RF) transmissions emitted from the GCS should not be detectable by hostile forces. To meet this requirement LPI technologies such as directional antennas, spread spectrum encoding and variable power output must be incorporated into the design of the data link. The airborne data link system transmissions will be difficult if not impossible to conceal. Variable power output transmitters and steerable antennas can be used on the UAV; however, the use of technologies such as spread spectrum may be impractical due to the bandwidth of the data involved. Data transmission over the data link must be reliable even in the event of intentional jamming. Therefore the data link system will require a sufficiently large anti-jam margin to be able to operate in an EW environment.

In the GCS the data link is interfaced with the Mission Planning and Control System (MPCS). The MPCS outputs command data to the data link processor/interface and receives status and sensor data from the data link. The data link processor/interface must supply data link derived UAV position data to the MPCS.

Table I contains a list of basic specifications for a UAV system data link. The specifications given in the table are the minimum requirements for a research UAV data link system; more features may be required depending on the mission and the payload of the UAV. The specifications of a UAV data link system used in a research environment must be based on both existing and anticipated UAV roles. A research oriented data link must be more versatile than an operational data link as data formats, frequencies and modulation types must be adaptable to evolving UAV roles. To insure that the system can

All Weather Operation	
Range	50 km
UAV Tracking Accuracy	25 m
Uplink Command Data Rate	10 Kbits
Down link Telemetry Data Rate	10 Kbits
Payload Data Rate	up to 63 Mbits
Data Compression	up to 20:1
LPI	
Error Detection and Compression	
Anti-jam Margin	30–40 dB
UAV Antenna Coverage	360 degrees
Directional Antenna(s)	
Frequency Band	5 or 15 GHz

Table I: UAV Data Link Requirements

be adapted to future requirements it should be designed in a modular fashion. This will enable the system to be upgraded as required at the minimum cost possible and with a minimum level of disruption to the research program.

Present DRES Data Link

The existing DRES data link must be upgraded to match the performance capabilities of the UAV subsystems presently under development. The present data link equipment is not capable of operating reliably at the ranges and data rates required to validate the performance of UAV systems being developed at DRES. The capabilities of the system must be expanded to enable the future use of sensors other than video cameras. The system must also be upgraded to enable the control of multiple vehicles.

Much of the present data link equipment must be replaced for logistical reasons. The GCS telemetry receivers have been discontinued by the manufacturer and will be very expensive to maintain in the future. The present ...nd uplink system is unreliable because of limitations in the original system design and the reliability of the existing hardware. The existing uplink system relies on transmitters with bandwidths which are much wider than required for transmitting the uplink 9600 baud RS-232 data stream. Reducing the bandwidth of the uplink would conserve radio frequency spectrum while at the same time reduce the possibility of interference from outside sources whether they be friendly or hostile. The performance of the data link could be improved through a combination of changing the transmission modulation and

by encrypting the data with an error detection/correction code. The present system checks the data stream for errors in individual words and for the proper placement of the frame sync word. If there is an error in either the data word or the frame sync word, the data word or the data frame is thrown away, no attempt is made in the present system to recover the corrupted data. The down link data is encoded on a 7.5 MHz subcarrier which is added to the payload video signal. This results in a requirement for the bandwidth of the down link data channel to be at least 7.5 MHz. The wide bandwidth of the down link channel decreases the performance of both the sensor (video) and status data channels. One solution is to encode the status data within the video data and reduce the bandwidth requirement of the data channel to approximately 4.0 MHz. The short term solution is to simply transmit the status data on a separate data channel similar to that used for the uplink. The disadvantage of this solution is that more RF hardware is required. The advantage of this solution is that the down link frequency is moved in to the UHF band where it is less susceptible to line of sight transmission problems.

The GCS tracking antenna is still maintainable and was recently overhauled by the manufacturer, this will extend its useful life by several more years. The UAV payload communications will have to remain in the S-Band (2200-2400 GHz) frequency range as long as this antenna is used as the primary data link receiving antenna.

The present DRES UAV control system relies on a portable co-operative radar system to determine the location of the UAV. The existing system is ten years old and is based on twenty year old technology. The system is difficult to maintain due to its design and the lack of readily available spares. The UAV must be equipped with a transponder to work with this tracking radar, this increases the weight and the cost of the payload which the UAV is required to carry. In the future tracking data could be provided by integrating a backup tracking system based on the data link system with a Global Positioning System (GPS) receiver integrated with the UAV autopilot system. The GPS system would be the primary source of navigation data while the data link system would provide backup tracking data whenever the GPS system was inoperable.

In conclusion the performance of the present data link equipment is suitable for use with a manned surrogate aircraft but is not reliable enough to be used as one of the basic support tools required for an unmanned air vehicle research program. Even if the system were technically capable of supporting the UAV program much of it would have to be replaced due to logistical considerations in the near future.

Proposed Update of the DRES Data Link

The operational UAV data link system described previously has many features which cannot be implemented using the existing DRES data link hardware. As always there are good reasons for maintaining a technically uncomplicated data link, the main reason being, the cost of updating the data link hardware. However as in the case of most systems designed with the military user in mind, an inexpensive piece of hardware is useless tc the operator if it can not carry out its designated function on the battle field. Simple data link systems have their place in training or low intensity combat situations; however, the electronic counter measures (ECM) and electronic support measures (ESM) available to sophisticated hostile forces will readily defeat a simple data link system. The use of a data link system which is easily disrupted will negate any potential benefits of deploying the UAV system.

Reducing the complexity and therefore the cost of the data link will not reduce the cost of the UAV system substantially. The most expensive components of an UAV system tend to be the payload sensor and to a lesser extent the guidance and control system. In many roles the sensor will be the most expensive and most vulnerable component of the system. In order to guarantee a reasonable level of success in carrying out the mission the data link has to operate under realistic conditions. If the data link is not able to perform properly in realistic battlefield conditions more vehicles will be required to carry out any single mission, this will not only affect the number of vehicles required but the logistics of delivering and maintaining the vehicles. The basic features required of the communication system are that it must be that it is rugged, simple to set up, difficult to disrupt, and have a low radio frequency (RF) signature. The low RF signature requirement is imposed by the enemies ability to detect, locate and destroy the aerial vehicle or more likely the GCS due to stray RF emissions.

The proposed DRES UAV communications system will consist of an integrated data link and tracking system. The system will include the following subsystems; the command uplink system, the sensor and data down link systems and a built in backup capability to track the air vehicle using information generated by the data link system. The new data link system will have the capability of operating in multiple frequency bands including the C and J frequency bands presently proposed for use by operational UAV systems. The system will also have the capability if and when required to control multiple air vehicles. The upgraded DRES research command and control system will incorporate many of the features required in an operational UAV system. One of the most important of these features and an area which DRES can make a

contribution to some aspects of is low probability of intercept communications for UAVs.

LPI COMMUNICATIONS

Low Probability of Intercept is a term used to describe the capability of a data link to avoid detection and interception. A UAV data link must utilize technology which implements LPI features to improve the chances of survival of the fielded system. Some aspects of LPI technology which might be applicable to an UAV communication system are spread spectrum modulation and directional antennas. These technologies are described in the following sections.

Spread Spectrum Communications

Spread spectrum modulation spreads the transmitted signal over a larger bandwidth than required in order to blend the signal into the ambient background noise. This makes the signal and thus the source of the signal harder to locate. The signal can be despread by friendly forces equipped with the appropriate receiver and the correct code key, while access to the data is denied to hostile forces. Spread spectrum communications can be implemented in a number ways, two of which are;

- through modulation by a high rate pseudo random code sequence (direct sequence) or,
- by shifting the carrier frequency of the data message by discrete amounts which are determined by a pseudo random code sequence (frequency hopping).

Spread spectrum modulation can also be used to simultaneously transmit more than one signal over the same frequency band through the use of different spreading codes. This inherent capability of spread spectrum communications will enable multiple vehicles to be controlled simultaneously using the same frequency band by programming each vehicle to decode only messages addressed to itself.

The implementation of spread spectrum modulation will result in a much more complex and expensive data link system. The cost of a custom

designed spread spectrum UAV communication system will be much higher than that of a less secure system based on standard off the shelf components. The use of spread spectrum technology also has technical draw backs, the transmitter and receiver in a spread spectrum system must be synchronized before the signal can be despread and the data can be properly received. This synchronization process takes a finite amount of time which can lead to a loss of information from the data stream when synchronization is lost. These loses can be minimized by implementing a protocol where messages are retransmitted if data is lost or is corrupted. Another potential problem area with the use of spread spectrum modulation is the bandwidth of the data generated by the payload sensor. It is difficult to spread the output data signals from many UAV sensors due to their inherently high bandwidth. A potential solution to this problem may be the use of data compression technology to lower the bandwidth required by the sensor data.

Antennas

Directional antennas can be used to deny hostile forces access to both the data transmitted by and location of the UAV system. This is accomplished by utilizing antennas with high gain narrow beamwidth patterns, with low side lobes, to transmit and receive the information signal. In order to intercept or jam the data link the hostile forces must be directly between the UAV and the GCS or be able to inject high levels of jamming power into the sidelobes of the UAV antenna systems. The disadvantage of using directional antennas in a UAV is that they must be continuously pointed towards the GCS. This leads to a requirement to equip the UAV with a steerable antenna system which will add both weight and complexity to the on-board UAV data link system.

Technical Risks and Benefits

Defeating either of the above noted LPI technologies compels hostile forces to employ sophisticated resources which may not be readily available. It may be possible to adapt commercially available spread spectrum data transmission system components for use in a research UAV data link system. Existing antenna elements are suitable for use in point to point communication systems; however, suitable control systems will have to be designed to steer these antenna elements. The LPI technologies described above can be used to create a framework for developing the required UAV communication systems of the future.

The design of spread spectrum communication systems is not an area of interest to DRES as this area of expertise is not within the mandate of DRES. The design of antenna systems for use on UAVs is of interest to DRES and is within the mandate of the UAV program. The performance of most antennas is altered by their operating environment; therefore, the organization which is responsible for UAV system design must have an in-house capability to predict the performance of UAV antenna systems. In order to implement LPI requirements the UAV antennas will have to be steerable. Because UAVs tend to be small highly maneuverable vehicles the design of these steerable antennas will be challenging. The antenna system must perform in a dynamic environment while at the same time being compact and light weight. In some cases multiple antennas may be required to guarantee at least minimum performance under all GCS to UAV geometries and all UAV attitude conditions.

PROPOSED UAV DATA LINK RESEARCH

The existing DRES UAV communications systems are comprised of an assortment of equipment which while functional could never be used as the basis for an operational UAV system. DRES has neither the personnel or the research tools to design a complete UAV data link system. However, DRES does have the resources to carry out research in selected areas of UAV data link research. One area of potential interest is the consolidation of the various antenna systems presently used by the DRES UAV data link system. The DRES system presently has separate antennas for the uplink, the down link and for the radar tacking system. If the down link is split into separate channels for payload data and telemetry data a separate down link telemetry antenna will also be required.

Separate antenna systems are required for each frequency used and each of the antenna systems will likely require more then one antenna to provide 360 degree coverage in azimuth. In the proposed UAV communication system only one frequency band would be utilized at a time, this would reduce the number of antenna systems required. The multi-purpose antenna system will consist of one or more antennas as required by the physical geometry of the UAV in order to obtain the necessary coverage.

The antenna system research will start with the design of an autopilot controlled antenna system for the Seneca aircraft. The first step in this research will be to design a system in which the existing fixed antenna systems will be adapted for control by the autopilot. The autopilot hardware and software will select the best antenna for use in transmitting or receiving data to or from the GCS. The antenna selection will be based on the relative positions of the GCS and the UAV and the attitude of the UAV. After the operation of this simple antenna controller has been verified the system will be used to evaluate the feasibility of using steerable antennas in place of the fixed antennas. The initial research will be carried out using the current data link frequencies; however, future research could be carried out in C or J-Band (5 or 15 GHz) which are two of the possible operational bands for UAVs. The research will focus on the design of compact steerable antennas for use on UAVs.

At J-Band the linear dimensions of an antenna are approximately one sixth of the linear dimensions of an antenna with the equivalent gain at S-Band. On the negative side the propagation losses are much higher at J-Band which will offset some of the added gain.

A steerable moderate gain antenna system will be capable of supporting the uplink command data, the down link status data, and the sensor data. The antenna system will be designed to be steered electronically or mechanically or by a combination of both depending on the configuration of both the host UAV and the type of elements chosen for the antenna.

The gain of the steerable antenna will be approximately 10 dB initially and the gain will be increased as practical experience is gained from using the prototype. A gain of 10 dB is equivalent to increasing the transmitter power by a factor of 10 over that of a similar system utilizing an omni-directional antenna system. The antenna pattern of an antenna with a 10 dB gain covers an angular area of approximately 60 degrees in both the elevation and azimuth planes. This is a sufficiently large angular area that precise control of the antenna will not be required. Once a basic set of control algorithms has been developed and verified it will be possible to enhance the performance of the system by gradually increasing the gain of the antenna system. In the short term access to the prototype steerable antenna will provide a more reliable data link for use in the UAV research program while also providing a test bed for the evaluation of algorithms for the control of steerable antennas on UAVs.

The experience obtained during this research will be useful in any conventional UAV frequency band and will also be of use in the development of data link repeater systems such as those required for voice and data channels, and also for specialized requirements such as sonobuoy repeaters.

The risks associated with this research are in the design of a light weight stabilized mount for the antenna elements and the selection and development of the antenna elements themselves. UAVs are lightweight vehicles which are very susceptible to buffeting by air currents and therefore the antenna mount and control system must be capable of compensating for the motion of the air vehicle with little or no error in the pointing angle of the antenna. The steerable antenna research program will use the DRES Seneca aircraft in order to monitor the performance of the antenna mount under operational conditions and to enable the control parameters to be varied as required.

Examples of the antenna element types to be investigated are reflector antennas, lens antennas and microstrip antennas. Each of these types of antennas has advantages that make them suitable for use on an UAV. Reflector antennas are relatively simple in design; however, they tend to be large and they must be steered mechanically. Lens antennas are relatively compact

antennas which are also mechanically steered. Microstrip antennas are low gain conformal antenna elements which are suitable for use in arrays. Microstrip antennas are thin lightweight devices which are relatively simple to fabricate. Their planar structure makes them ideal for use on aerial vehicles where they can be bonded onto or made an integral part of the fuselage. Arrays of microstrip elements can be steered electrically or mechanically or by a combination of both as requirements dictate. The feed network required to control and drive the array can be fabricated as part of the array due to the planar structure of microstrip arrays. Microstrip antennas are made using printed circuit board technology and once a design is completed and verified multiple copies can be easily fabricated.

Microstrip antennas were initially seen as narrow band devices. In the past several years much work has been carried out into expanding the capabilities of microstrip antennas and to analyzing their performance in arrays. The use of microstrip antenna arrays on UAVs has been described in a number of reports on antenna system design [1] [2].

Specialized UAV Antenna Requirements

In some UAV missions the antenna system is an integral part of the payload. Some examples of these specialized antennas are data link repeater antennas and ESM receiver antennas. In many cases these antennas must be custom designed to operate on the available airframe to enable a particular mission to be carried out.

A byproduct of the UAV antenna research will be the development of an in-house expertise in UAV antennas. In the future this expertise can be used by the Canadian Forces in the selection and evaluation of data links for UAVs.

CONCLUSION

To obtain the maximum benefits from a UAV system it is necessary to have a well designed robust data link to control the UAV and to receive payload data from the UAV. The present DRES data link consists of equipment which was acquired in the past to support various projects, and which has now been patched together to support the UAV program. In order to carry out future UAV research a decision must be made to up date the existing data link system in a coherent manner.

One aspect of updating the data link system is the design of data link antennas for the surrogate aircraft. This will allow the surrogate aircraft to be used as demonstration platforms for UAV data link research. Proper antenna system performance is critical in maintaining a reliable communications link with a UAV which is operating in a hostile operational environment. The radiation pattern of the antenna system has to be controlled so that the transmitted energy is radiated in the desired direction. This enables the use of lower power transmitters and prevents hostile forces from intercepting or jamming the communication link. The antenna system is an important subsystem of the overall UAV mission control system. If the antenna system does not perform as required the UAV will not be able to carry out the demanded mission.

The antenna system has to be designed from the ground up to integrate both physically and operationally with the UAV. The physical structure has to be compact and light weight to fit in the UAV. The control of the antenna system has to be integrated with the autopilot system to ensure that the best antenna, if there is more than one, is always pointed at the GCS.

This report has put forward a possible frame work for future research in data links for UAVs including a proposal for research into the feasibility of steerable antennas for UAVs. The work would commence with the integration of the existing antenna system with the autopilot as an antenna controller. At the same time work would begin on the design of a steerable antenna with a gain of approximately 10dB. This work would provide a basis for the design of higher gain antennas and special purpose antennas such as those required by communications repeaters and sonobuoy repeaters.

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The Unmanned Vehicle Systems Group (UVSG) at Defence Research Establishment Suffield (DRES) has a mandate to conduct research in the area of Unmanned Air Vehicles (UAVs) and their associated control systems. The major focus of this research is the command and control of UAVs. The command and control system (ACCS), the ground control station (GCS), and the data links required to enable communication between the ACCS and the GCS. This report describes the data links presently used by DRES and the proposed improvements to these systems.

The improvements include the implementation of low probability of intercept (LPI) technology in the UAV data link. Brief descriptions on the benefits of spread spectrum modulation and directional atennas are presented. Possible areas of research in the development of directional antennas for UAVs are presented along with a description of how research in this area would proceed in the future.

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